Non-Polymeric Membranes for Ambient-Temperature Fuel Cells

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Fuel cells are attractive alternatives to combustion engines for electrical power generation because of their very high efficiencies and low pollution levels. Polymer electrolyte fuel cells, those most viable for mobile applications, suffer from the humidification requirements of the polymer, which limits the temperature of operation to ~100ºC, and from its permeability to methanol and hydrogen, which lowers fuel efficiency. We report here the operation of fuel cells based on inorganic proton-conducting electrolytes, specifically, "solid acids", that address many of the issues facing polymer fuel cells. Solid acids are compounds, such as $CsHSO_4$, whose chemistry and properties are intermediate between those of a normal acid (*e.g.* H_2SO_4) and a normal salt (*e.g.* Cs_2SO_4). The proton conductivity of these materials can reach values as high as 10^{-2} $\Omega^{-1}cm^{-1}$ when heated to slightly elevated temperatures [1-3]. The transport process does not require humid atmospheres and the materials are stable to temperatures as high as 250ºC. Unfortunately, all known solid acids of high conductivity suffer from solubility in water and extreme ductility in the high temperature phase, and thus they have not been seriously examined as possible fuel cell electrolytes. In this work, we demonstrate high performance H_2/O_2 fuel cells with good stability by operation at temperatures slightly above the boiling point of water.

Membrane electrode assemblies (MEAs) were prepared as follows. A powdered layer of $CsHSO_4$ was sandwiched between two electrocatalysis layers comprised of $CsHSO_4$, Pt black, carbon black and a volatile organic. These layers were, in turn, placed between two sheets of porous, graphite current collectors. The entire assembly was uniaxially pressed at 490 MPa, to yield a dense electrolyte membrane (1-1.5 mm in thickness) with good mechanical contact to the electrocatalyst layers. Fuel cell polarization curves were collected at slightly elevated temperatures from MEAs placed in a standard graphite test station. Upon heating to the measurement temperature, the organic phase in the electrode evaporated, leaving behind a porous electrode structure.

The current densities of such a single cell fuel cell, exposed to H_2O-saturated H_2 at the anode and H_2O-saturated O_2 at the cathode and held at 160ºC, are presented in Figure 1. The platinum content or "loading" was 18 mg/cm^2 and the membrane thickness 1.4mm. The solid curve reflects the initial measurement and the dotted, the measurement after 18 hours of exposure to humid air. The anode and cathode gases were humidified during fuel cell operation only in order to explicitly establish the open circuit potential. Similar results were obtained for operation with dry gases. It is immediately apparent that despite the water solubility of $CsHSO_4$ and its ability to undergo extensive plastic deformation at high temperatures, excellent and prolonged fuel cell performance is possible. Furthermore the open circuit voltage of the $CsHSO_4$-based cell is significantly higher than that normally obtained from polymeric systems, which may ultimately result in improved fuel cell efficiencies. While these preliminary results are encouraging, several challenges must be overcome before solid-acid fuel cells (SAFCs) can become viable technologies, and these are outlined here.

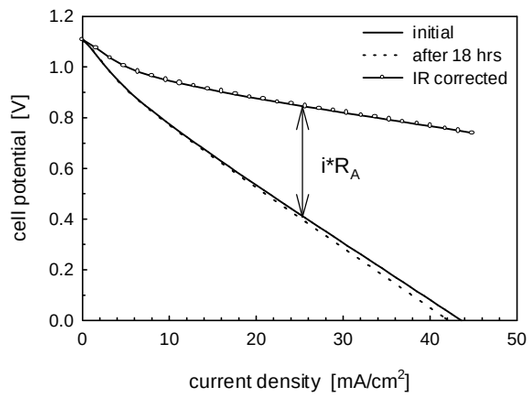

Figure 1. Cell voltage versus current density (polarization curve) for a $CsHSO_4$ fuel cell operated at 160ºC under moist H_2 and moist O_2 at the anode and cathode respectively (total pressure of 1 atm). Platinum loading of 18 mg/cm^2. Solid line: initial measurement; dotted line: measurement after 18 hrs of exposure to humidified air at both electrodes; dashed/dotted line: IR corrected result for initial measurement

References

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